Journal of the Arkansas Academy of Science

Volume 70 Article 22

2016

Sequence Stratigraphy of the St. Joe and Boone Formations, Lower Mississippian (Kinderhookian-Osagean), Southern Ozark Region

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Running Title: Sequence Stratigraphy of the St. Joe and Boone Formations

Abstract

The Lower Mississippian (Kinderhookian-Osagean) St. Joe and succeeding Boone Formations are well exposed in northwestern Arkansas, southern Missouri, and northeastern Oklahoma, forming the Springfield Plateau of the southern Ozark region. This interval represents a single, third order, transgressive-regressive eustatic cycle deposited broadly across the North American craton. The initial transgression during the Kinderhookian covered the regional erosional surface developed on either the Devonian-Lower Mississippian Chattanooga Shale, or older units with crinoidal packstones deposited as platform successions or transported as down-ramp slurries. The Boone Formation is divided informally into lower and upper divisions that reflect differences in eustatic sea level. The lower Boone (early Osagean) is composed primarily of calcisiltites with interbedded dark, nodular, penecontemporaneous chert deposited below effective wave base during the maximum flooding interval of the third-order eustatic cycle. The upper Boone (late Osagean-early Meramecian?) represents the third-order highstand, and regressive sequences comprising crinoidal grainstones and packstones, mostly deposited within effective wave base. In contrast to the lower Boone, the upper Boone carbonates are interbedded with white to light gray, later diagenetic chert, the product of groundwater replacement. The formally named Short Creek Oolite Member of the upper Boone Formation is only sporadically developed, probably transported as down-ramp slurries across the region during regression. Across the Springfield Plateau, the Boone Formation is separated by a type I sequence unconformably from succeeding strata of Meramecian or younger age.

Introduction

Lower Mississippian (Kinderhookian-Osagean) strata exposed in Arkansas, Missouri, and Oklahoma are predominately limestones, including packstones, grainstones, calcisiltites, and associated chert, both penecontemporaneous and later diagenetic. The sequence stratigraphy of these strata comprises a third order eustatic cycle that is bounded at the base and top by regional unconformities (Manger and Shelby, 2000). The Lower Mississippian strata are recognized as the St. Joe Formation, which represents the transgressive systems tract (TST), and the Boone Formation, which represents the maximum flooding interval (MFI), highstand systems tract (HST) and a regressive systems tract (RST) of that third order cycle (Manger and Shelby 2000). Understanding the order in which these strata were emplaced is important because it provides insight into the geologic history of Arkansas and surrounding areas, the chert development within the Boone, and the potential for oil and gas plays.

Geologic Setting

The southern Ozark region of northern Arkansas occupies the south flank of the Ozark Dome. The dome is an asymmetrical uplift centered in southeastern Missouri exposing a core of Precambrian granite and rhyolite in the St. Francois Mountains (Manger et al., 1988) (Fig. 1). There are three plateau surfaces that increase in elevation as a result of the Ozark Dome uplift (Fig. 1). The oldest of the three, the Salem Plateau, is underlain mostly by Lower Ordovician limestones and dolomites, with associated orthoquartzitic sandstones. The Springfield Plateau comprises the Lower Mississippian St. Joe Limestone and succeeding chert-bearing limestone of the Boone Formation. The youngest of the three plateaus is the Boston Mountain Plateau, which is located farthest south of the Ozark Dome center. It consists of unconformity-bounded intervals of sandstones, shales, and some limestones representing the Chesterian, Lower Morrowan, Upper Morrowan, and Atokan Series (Manger et al., 1988). Structurally, there are

numerous, closely spaced, parallel to subparallel, northeast-southwest, and subordinate east-west trending normal faults across the region.

During the Osagean, a carbonate platform developed, commonly called the Burlington Shelf (Lane 1978), located across most of present day Missouri and eastern Kansas. This shelf produced abundant crinozoan detritus and carbonate mud within effective wave base that was transported down ramp as slurries in a lobate manner that covered most of northwestern Arkansas, northeastern Oklahoma, and southwestern Missouri (Manger and Shelby 2000).

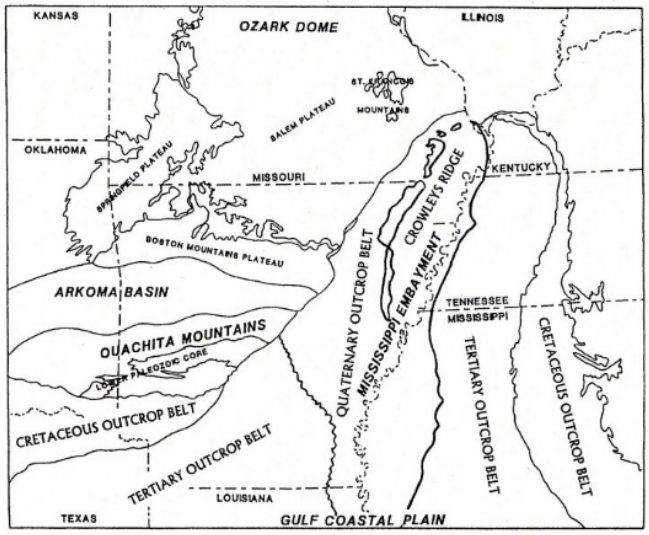

Fig. 1. Geologic Provinces of Arkansas and Adjacent Areas, Southern Midcontinent (modified from Manger et al. 1988).

Lithostratigraphy

The transgressive-regressive sequence of the Lower Mississippian comprises the St. Joe (Hopkins 1893), and the succeeding Boone Formations (Branner 1891, Simonds 1891) of northwest Arkansas (Fig. 2). The St. Joe Formation consists of crinoidal packstones and carbonate mudstones that were deposited as down ramp slurries coming from the Burlington Shelf. In northwestern Arkansas, the St. Joe Formation is subdivided into four members (in ascending order): the Bachelor, Compton, Northview, and Pierson (Manger and Shelby 2000). The Bachelor Member sits uncomformably as a green calcareous shale atop the Chattanooga Shale (Upper Devonian). However, when the Bachelor overlies formations as old as Middle Ordovician, it is an orthoquartzitic sandstone. The Northview Member is a calcareous siltstone separating the underlying Compton and overlying Pierson

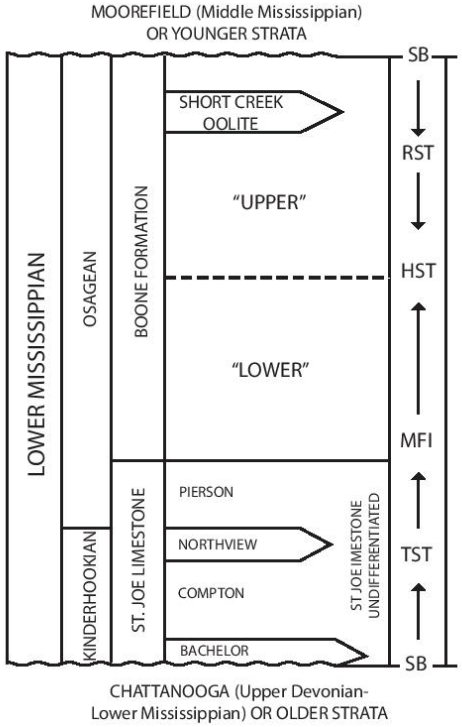

Fig. 2. Lower Mississippian Lithostratigraphy- Southwestern Arkansas (modified from Manger and Shelby 2000).

Members, both crinozoan packstones (Fig. 3). It should be noted that in Missouri the lithostratigraphic nomenclature of the St. Joe is not recognized. Instead, the equivalent interval is divided into the Bachelor, Compton, Northview, and Pierson Formations (Thompson 1986). To avoid this "state-line fault, these are recognized as members of the St. Joe Formation in Arkansas. The succeeding Boone Formation in Arkansas is separated informally into lower and upper divisions informally based on different types of chert development (Manger and Shelby 2000) (Fig. 2). However, like the St. Joe Formation, the Boone Formation is not recognized in Missouri, where the interval is divided into the Reed Springs, Elsey, and Burlington-Keokuk Formations (in ascending order) (Thompson 1986). The lower Boone is comprised of calcisiltites interbedded with dark, nodular penecontemporraneous chert. This chert represents the reprecipitation of silica derived from volcanic ash falling through the water column and accumulating below the sediment water interface before the carbonate sediment of the lower Boone was completely lithified. Alternatively, the upper Boone consists of crinoidal grainstones and packstones interbedded with white, to light gray, later diagenetic chert. The silica of the diagenetic chert was sourced from the same

volcanic ash as the penecontemporaneous chert, but it is a groundwater replacement along the carbonate bedding planes (see Cains et al., this volume for further discussion of chert). The Short Creek Oolite, the only formally recognized member of the Boone, occurs in the upper part of the interval, but is only sporadically developed (McFarland 2004). This member was transported as down-ramp slurries during the upper Boone regression. The Boone Formation is separated by a type 1 sequence unconformity from succeeding strata of Moorefield or younger strata.

Sequence History

There are five different orders of eustatic cyclicity that produced the Lower Mississippian carbonate succession in the southern Ozarks. The first-order cycle named Kaskaskia (Sloss 1963) is bounded by type 1 sequence unconformities. It begins in the Lower Devonian and extends to the Mississippian-Pennsylvanian boundary. Its MFI occurred during the Lower Osagean. Two second-order cycles are present within the Devonian and Lower Mississippian portion of the first order sequence: Kaskaskia I and Kaskaskia II (Sloss 1982). Kaskaskia I begins at the base of the Devonian and extends to the type 1 sequence unconformity separating the Upper Devonian from the Lower Mississippian. The succeeding Kaskaskia II extends from the Lower Mississippian to the Mississippian-Pennsylvanian boundary, with its maximum flooding interval at the same point in the Lower Osagean as the first-order cycle. Superimposed on the Kaskaskia II cycle are two third-order cycles and 13 fourth-order cycles. The third and fourth order maximum flooding intervals occurred in the Lower Osagean. The first, third-order eustatic cycle of the Kaskaskia II cycle spanned the Kinderhookian – Osagean boundary in the upper St. Joe Limestone (Northview-Pierson contact), Lower Mississippian, which represents the TST (Manger and Shelby 2000). However, it is worth noting that during this transgression, there was a slight drop in sea level, most likely as a fourth-order cycle, allowing a terrigenous clastic influx, resulting in siltstone deposition of the Northview Member. Following this slight regression, transgression resumed, reaching the MFI in the lower Boone Formation (Fig. 4). The lower Boone MFI is coeval with those of the first-order Kaskaskia and the second-order Kaskaskia II cycles. The succeeding HST and RST sequences are represented by the upper Boone (Fig. 5), which becomes grain-dominated up-section as the regressive sequence brought deposition into effective wave base.

Conclusions

The Lower Mississippian (Kinderhookian-Osagean) of the southern Ozarks represents a single, third-order, transgressive-regressive eustatic cycle that is bounded unconformably by type 1 sequence boundaries. The St. Joe Formation (Kinderhookian-Osagean) represents the transgressive sequence and is composed of crinoidal packstones and carbonate muds.

The lower Boone Formation (Early Osagean) represents the maximum flooding interval and is composed of calcisiltites with dark, nodular penecontemporaneous chert, while the upper Boone Formation (Late Osagean) represents the highstand/regressive sequence and is composed of crinoidal packstones and grainstones with white to light gray, later diagenetic chert. Both the St. Joe and Boone Formations are separated unconformably from older and younger strata at their base and top, respectively.

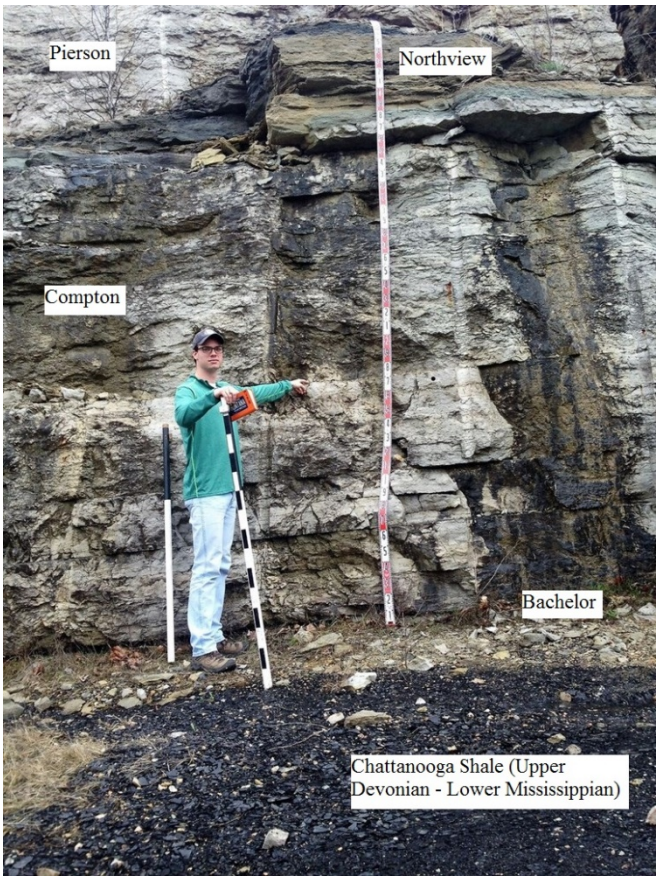

Fig. 3. Outcrop of St. Joe Formation (TST) exposing each member, I-49 road-cut near Jane, Missouri.

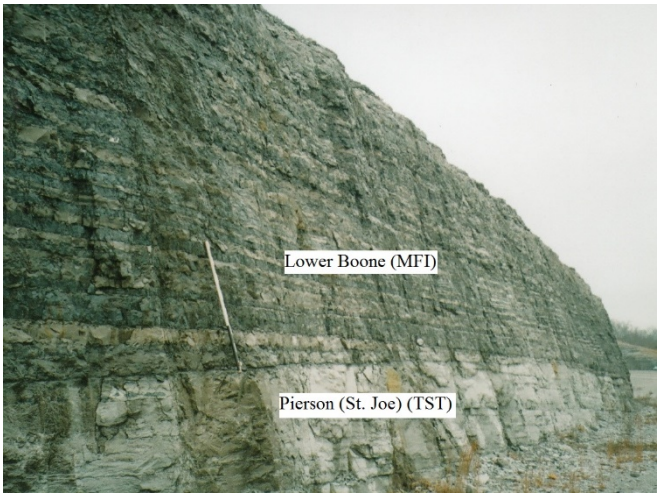

Fig. 4. Outcrop exposing the TST and MFI contact at the St. Joe-Boone boundary, I-49 road-cut near Pineville, Missouri.

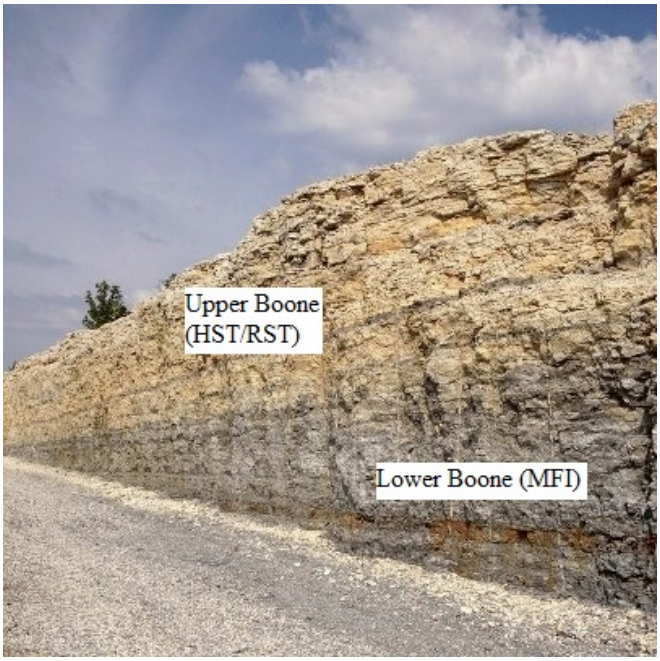

Fig. 5. Outcrop exposing the contact between the MFI and the HST/RST in the Boone Formation, I-49 road-cut near Pineville, Missouri.

Acknowledgements

Thanks to my co-workers in the Lower Mississippian Research Group in the Department of Geosciences – Julie Cains, Forrest McFarlin, John Philbrick, and advisor Dr. Walter Manger - for their help and support in seeing this paper to completion. The Department of Geosciences, University of Arkansas, defrayed page charges for this paper.

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